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(54) Method of sound signal processing and device for implementing the method

(57) Method and device for sound signal processing in a signal processing device including a main signal path comprising

- input means (1,2),
- a signal processor unit (3), and
- output means (4,5),
  the signal processor (3) being controllable via several control parameters supplied from a programmable controller (6).

The control parameters are generated continuously and dynamically in the programmable controller as a function of at least the sound environment.

Further parameters can be supplied to the programmable controller for influencing the generating of control parameters for the signal processor, such as:

- the signal to be processed and/or
- the output signal from the signal processor unit and/or
- time of day and/or
- ambient temperature and/or
- ambient air humidity and/or
- ambient light and/or
- telecoil detection and/or
- voice recognized spoken control words etc.

Although the invention is intended primarily for use in hearing aids, many other uses can be envisaged.

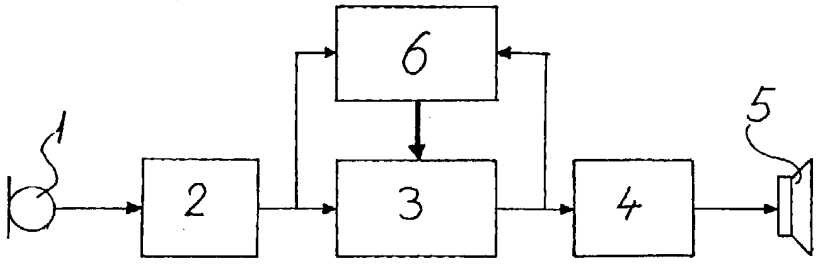

Fig. 1

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Description

[0001] The present invention relates to a sound signal processing method of the kind set forth in the preamble of claim 1 and a device for implementing such a method.

[0002] In signal processing methods of this kind, which are primarily intended for use in hearing aids of different kinds, it is known from e.g. EP-064,042 to provide a signal processor which is controlled by several control parameters supplied from a programmable controller. In the above document, the programmable controller is able to discriminate between a limited number of discrete acoustical environments and set the control parameters to provide a limited number of preprogrammed transfer functions for the signal processor, the transfer functions being selected to best suit the particular acoustical environment. The changing of control parameters may be performed manually or automatically, the automatic changing being dependent on the acoustical environment as detected in the signal processing unit.

[0003] It is the object of the present invention to provide a signal processing method of the kind mentioned above, with which it is possible to achieve a continuum of dynamically generated control parameters for the signal processing, whereby an almost unlimited number of different signal processings of the input signal can be performed, primarily dependent on the input signal.

[0004] This is achieved with a signal processing method of said kind, which in accordance with the present invention comprises the features set forth in the characterizing clause of claim 1.

[0005] With this method it is possible to change the processing parameters for the signal processing unit dynamically and continuously in accordance with the instantaneous input signal, so that the processing at all times can be optimized to provide the desired output signal.

[0006] In a preferred embodiment, further parameters may be used to influence the generating of the control parameters and accordingly the processing. These parameters may comprise, but are not limited to, the output signal from the signal processor unit, time of day, ambient temperature, ambient air humidity, ambient light, telecoil detection, voice recognized spoken control words, pulse rate of the user, etc., all of these parameters being supplied to the programmable controller in order to detect different conditions with respect to e.g. the environment, the "state" of the user, etc.

[0007] The different parameters may initially influence the generated control parameters according to a preprogrammed function in the programmable controller, but will during a training period be changed and adjusted in accordance with the preferences of the user, as communicated to the programmable controller, thereby providing a trainable performance of the signal processing, in which the starting point is fixed, but the adjustments are unknown and the final programming is unlimited.

[0008] The signal processing method is preferably implemented in micro-processor technology and comprises fixed and adjustable programming, the adjustments of the adjustable programming being normally performed by the user possibly in cooperation with a fitter. The digital signal processor unit may be implemented in micro-processor technology as a fixed calculating structure, e.g. a FIR-filter, an IIR-filter, a neural network or the like, with variable parameters controlled by the programmable controller which is preferably implemented in the same micro-processor as the signal processing unit. The programmable controller may perform functions like spectral analysis, statistical analysis, mathematical functions, logical functions, etc., in order to generate appropriate control parameters for the digital signal processor unit.

[0009] In the following detailed part of the present description, the invention will be explained in more detail with reference to the exemplary embodiment of a method of signal processing and a device for implementing the method according to the invention, as illustrated schematically in the drawings, in which

Figure 1 shows the main blocks of a hearing aid implementing the method in accordance with the invention,

Figure 2 shows a more detailed schematic block diagram of an example of signal processing using a programmable controller with pre-processing, neural network and post-processing to generate the parameters for a signal processing unit comprising separate filter and gain blocks, and

Figure 3 shows the performance of the signal processing system in Figure 2 as a function of the control parameters generated in the pre-processing.

[0010] The hearing aid shown in Figure 1 includes a main signal path comprising a microphone 1, an A/D-converter 2, a digital signal processor unit 3, a D/A-converter 4 and a telephone 5. The processing in the digital signal processor 3 is controlled by several control parameters supplied from a programmable controller 6. The programmable controller 6 generates the control parameters continuously and dynamically as a function of the digitized version of the signal to be processed, delivered by the A/D-converter 2. In the hearing aid shown in Figure 1, the programmable controller 6 is also receiving the digital output signal from the digital signal processor unit 3 for influencing the generating of control parameters for the digital signal processor 3. Further parameters, as mentioned above, may be supplied to the programmable controller 6 for influencing the generating of control parameters. The digital signal processor unit 3 is understood to be a fixed calculating structure, e.g. a FIR-filter, an IIR-filter, a neural network or the like. It is essential when choosing this fixed calculating struc-

ture with adjustable parameters that the structure can change in characteristics by adjusting the parameters so that the desired signal processing can be achieved.

[0011] By the shown structure the following advantages are achieved:

[0012] The main signal path is of a constant nature comprising A/D-, D/A-converter and the digital signal processing unit 3 which once and for all can be constructed to have sufficient accuracy and resolution to achieve the desired high signal quality.

[0013] New forms of signal processing will only indirectly influence the signal path by being implemented in the programmable controller 6 which means that the system will not have to be redesigned with respect to signal/noise-ratio etc., for each new algorithm to be added.

[0014] With this new concept of a hearing aid, it will be necessary to revise the traditional concept of serial/parallel manipulation of the signal which cannot be converted sensibly in this new concept. Accordingly, the opinion of the concept of a hearing aid and what it can do will have to be revised.

[0015] The adjustment of the hearing aid will possibly comprise a basic adjustment of the hearing aid in order to compensate for the hearing loss of the patient, which adjustment will be based on traditional audiologic diagnostics and/or other, possibly individual characteristics like lifestyle, personal qualities, etc., and followed by further adjustments of the system in the user's own environment in accordance with the user's preferences. The aim of these adjustments will be to provide the user with a sound perception in accordance with the users preferences under different conditions. The system for fitting the hearing aid will comprise the physical hearing aid and possibly stationary equipment at the fitter laboratory and user portable equipment for use in the user's own environment. The communication between the user and the fitting equipment may be performed by voice control, manual keyboard control, physiologic activity control, using electrodes or other sensors connected to the user, etc., and the communication between the fitting equipment and the hearing aid may be wired or wireless.

Example of signal processing implemented in a system as described above:

[0016] To illustrate the invention, an example is given of a system implementing signal processing as described above. Figure 2 schematically shows the signal processing system. Within the system, the programmable controller 6 is built up of three components, a pre-processing block 7,8, a neural network block 9 and a post-processing block 10. The signal processing unit 3 is composed of a filter block 11 succeeded by a gain block 12, both getting parameters from the post-processing block 10. Within the pre-processing block 7,8 the overall rms-energy (RMS_{Total}) 8 of the input signal and the ratio between energy at high and low frequencies (Tilt) 7 in the input signal are estimated. According to the instantaneous input signal the control parameters RMS_{Total} and Tilt change the processing parameters for the signal processing unit 3, i.e. the filter coefficients and the gain scaling, dynamically and continuously. The individual adjustment of the system performance to fulfil the user's preference is carried out by training the neural network 9 to match the individual requests according to the control parameters. The achieved functionality is schematically shown in Figure 3.

Claims

1. Method of sound signal processing in a signal processing device including a main signal path comprising

   - input means,
   - a signal processor unit, and
   - output means,

   the signal processor being controllable via several control parameters supplied from a programmable controller, **characterized** by generating the control parameters continuously and dynamically in the programmable controller as a function of at least the sound environment.

2. Method in accordance with claim 1, **characterized** by further parameters being supplied to the programmable controller for influencing the generating of control parameters for the signal processor.

3. Method in accordance with claim 2, **characterized** by the further parameters comprising:

   - the signal to be processed and/or
   - the output signal from the signal processor unit and/or
   - time of day and/or
   - ambient temperature and/or
   - ambient air humidity and/or
   - ambient light and/or
   - telecoil detection and/or
   - voice recognized spoken control words etc.

4. Method in accordance with any of the preceding claims, **characterized** by the programmable controller comprising fixed programming and adjustable programming.

5. Method in accordance with any of the preceding claims, **characterized** by the signal processor unit implementing a fixed calculating structure, e.g. a FIR-filter and/or an IIR-filter and/or a neural network, with variable parameters controlled by the

programmable controller.

6. Method in accordance with any of the preceding claims, **characterized** by the programmable controller being programmed to perform spectral analysis and/or statistical analysis and/or mathematical and logical functions, in order to generate the control parameters for the signal processor.

7. Method in accordance with any of the preceding claims, **characterized** by the programmable controller and/or the signal processor being preceded by a pre-processing and/or succeeded by a post-processing.

8. Device for implementing the method in accordance with any of the claims 1-7, **characterized** by the signal processor (3) being implemented in microprocessor technology as a digital signal processor and the programmable controller (6) being implemented in microprocessor technology, possibly in the same microprocessor as the digital signal processor (3).

9. Device in accordance with claim 8, **characterized** by being implemented in any of the following:

   a) a hearing aid
   b) a mobile telephone
   c) a sound reproduction system
   d) a head set
   e) a hearing protection device
   f) a cochlear implant, etc.

10. Method for adjusting a device in accordance with claim 8 or 9 comprising

    a) basic adjustment of the transfer function in accordance with audiologic diagnostics and/or other individual characteristics like lifestyle, personal qualities, etc., to compensate for the hearing loss of the patient,
    characterized by further comprising:
    b) further adjustment of the programmable controller (6) to influence the parameters for the digital signal processor (3) in order to make the transfer function dependent on the acoustical environment and possible further parameters influencing the patient's perception of the sound, to achieve a final adjustment as close as possible to the requirements of the individual user under different situations.

11. Method in accordance with claim 10, **characterized** by further adjustments being performed by the user, possibly in co-operation with the fitter.

12. Method in accordance with any of the claims 10 or 11, **characterized** by comprising the use of stationary adjustment equipment and/or user portable adjustment equipment communicating wired or wireless with the device.

13. Method in accordance with claim 12, **characterized** by the stationary adjustment equipment and/or the user portable adjustment equipment being controlled by any of the following:

    a) voice control
    b) manual keyboard control
    c) physiologic activity control, using electrodes or other sensors connected to the user.

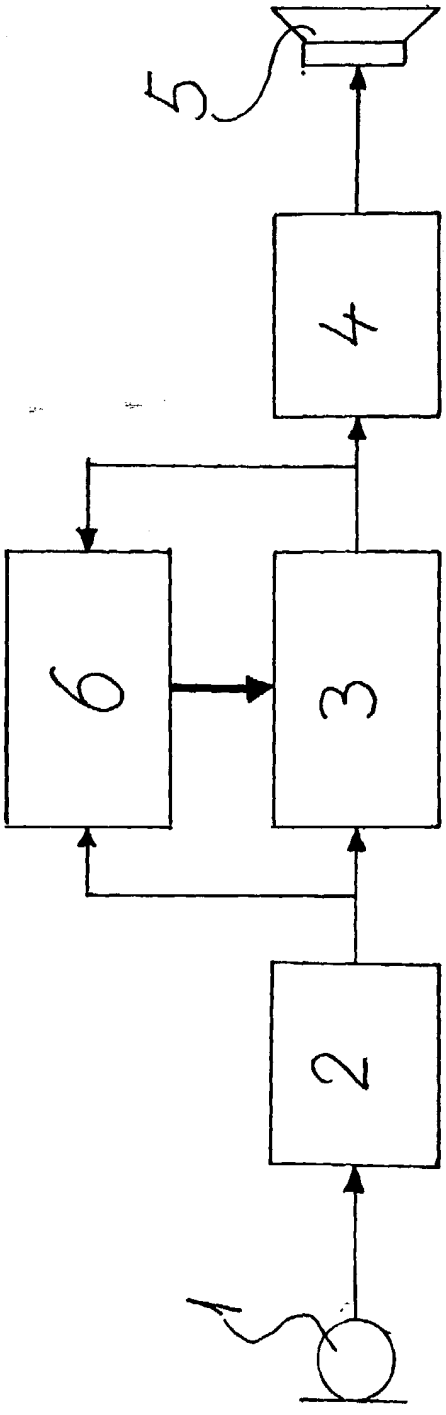

Fig. 1

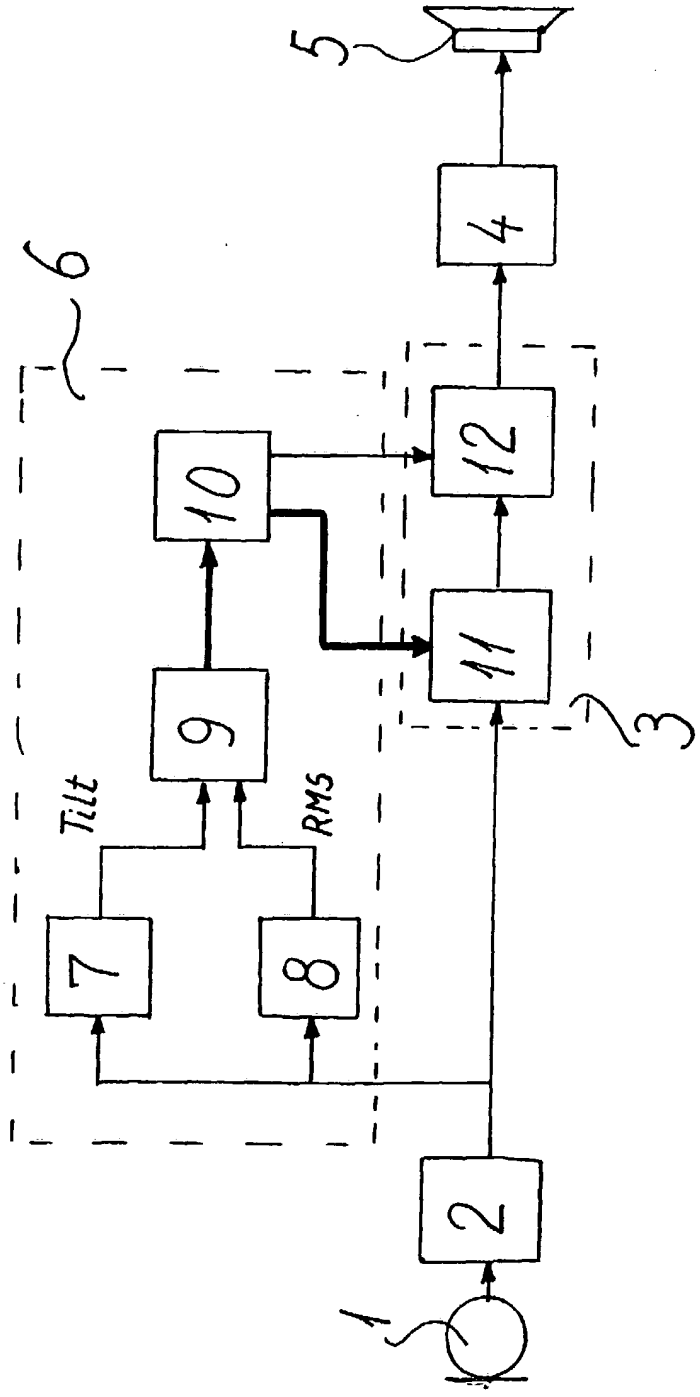

Fig. 2.

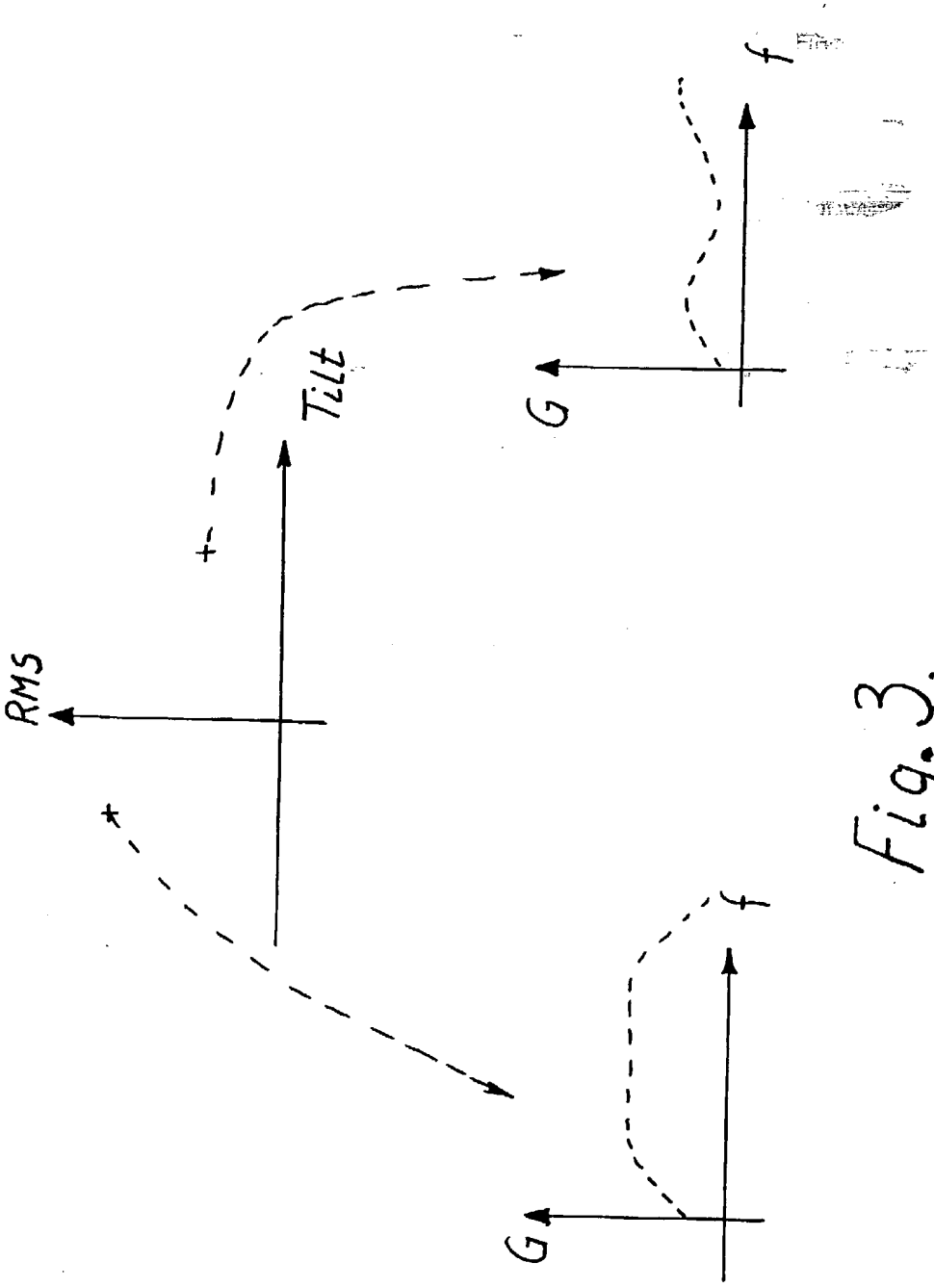

Fig. 3.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 11 0711

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	WO 90 05437 A (NICOLET INSTRUMENT CORP) 17 May 1990 * abstract; figures * * page 10, line 1 - page 17, line 9; figures *	1-4,8-10	H04R25/00
X	US 5 608 803 A (MAGOTRA NEERAJ ET AL) 4 March 1997 * column 1, line 45 - column 2, line 46 *	1,8-10	
X	US 5 717 770 A (WEINFURTNER OLIVER) 10 February 1998 * column 2, line 56 - column 3, line 18; claim 1; figures *	1,8-10	
X	US 5 754 661 A (WEINFURTNER OLIVER) 19 May 1998 * column 2, line 46 - column 3, line 17; claim 1; figures *	1,8-10	
X	EP 0 814 635 A (SIEMENS AUDIOLOGISCHE TECHNIK) 29 December 1997 * column 4, line 28 - column 5, line 21; figure 1 *	1,8,10	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04R
A	US 5 636 285 A (SAUER JOSEPH) 3 June 1997 * column 2, line 60 - column 4, line 39; figures *	1,3	
A	EP 0 537 026 A (UNITRON IND LTD) 14 April 1993 * abstract; figures *	1,10-13	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	4 December 1998	Gastaldi, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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